Quality-of-Service Provisioning using Hierarchical Scheduling in Optical Burst Switched Network

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Abstract: The issues of providing QoS in WDM OBS network are attracting increasing attention in the networking community. One of the key issues is to design efficient algorithms for burst scheduling or more precisely their bandwidth reservation. An ideal scheduling algorithm should be able to process a control packet fast enough before the burst arrives, and yet be able to find a suitable void interval for the burst as long as there exists one. Otherwise, a burst may be unnecessarily discarded either because a reservation cannot be completed before the burst arrives or simply because the scheduling algorithm is not smart enough to make the reservation. In this paper, we propose an OBS network model using the per-hob-behaviors with its three methods of forwarding of the differentiated service to create the burst packets and to implement the burst hierarchical scheduling technique using Weighted Round-Robin and Priority Queueing (WRR_PQ) in order for the network model to support QoS in terms of lower blocking probability, higher resource utilization and lower burst loss rates.

I. INTRODUCTION

Optical burst switching [1-2] (OBS) has been receiving attention as one of the most promising technologies to carry the next-generation optical Internet. OBS combines the advantages of optical circuit switching and optical packet switching, while overcoming their shortcomings. OBS uses separate wavelength to transmit Burst Header Packets (BHP) and Data Bursts (DB). A BHP is sent out ahead of its corresponding DB to reserve a wavelength along the path of the burst. Based on a one-way reservation protocol, OBS precedes a DB with a BHP in a pre-defined offset time, without waiting for an acknowledgement before beginning of the data transmission as shown in Figure 1.

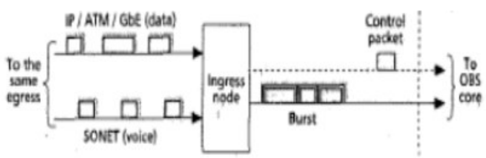

Figure 1: OBS Operation

In OBS network, supporting differentiated services in the WDM layer is an important issue. Providing basic service differentiation at WDM layer can facilitates and complement a QoS enhanced version of IP. Among various QoS parameters, burst-blocking probability is a critical one for service differentiation in an OBS network.

Quality-of-Service (QoS) is a broad term, which has many interpretations. QoS can be defined as the concept of applying and ensuring specific, quantifiable performance levels on a shared network. Performance can be assessed based on physical measurements of the network, the methods by which network traffic is prioritized, and on how the network is managed. Besides that, QoS provides end-to-end service guarantees and policy-based control of an IP network's performance measures, such as resource allocation, switching, routing, packet scheduling and packet drop mechanisms.

The network's capability to deliver service needed by specific network applications with some level of control over performance measures

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i.e. bandwidth, delay and jitter, and loss is categorized into three service levels [3].

- Best-effort service – Basic connectivity with no guarantee as to whether or when a packet is delivered to the destination, although a packet is usually dropped only when the router input or output buffer queues are exhausted.
- Differentiated service – In differentiated service, traffic is grouped into classes based on their service requirements. Each traffic class is differentiated by the network and serviced according to the configured QoS mechanisms for the class. This scheme for delivering QoS is often referred to as COS.
- Guaranteed service – A service that requires network resource reservation to ensure that the network meets a traffic flow's specific service requirements. It is also referred to as hard QoS because it requires rigid guarantees from the network.

Besides describing the levels of QoS, the quality-of-service is also depicting by its performance, dependability and security properties [4]:

- Reliability of a service: This includes the availability of a service, failure rate of a service, repair rate i.e. the time it takes to get the service operational again and etc.
- Security of a service: this could be explained as the following examples such as the possibility of authenticating where or from whom the information have been sent, the possibility of securing integrity of information and the strength of its cryptographic algorithms to keep information hidden and etc.
- Performance of a service: the items that fall into this category would be the throughput of a service, loss rate and delay distribution for information sent through a network.

Current IP only provides best effort service to deliver variable length packets. The future Internet may demand differentiated services for multimedia applications. For the optical Internet to be truly ever-present, one must address among other important issues is the techniques or methods the WDM layers can support differentiated services. To date, no efficient optical buffer is available. The use of electronic buffers necessitates O/E/O conversions, which must be avoided in all-optical network where data is kept in the optical domain at all intermediate nodes. This calls for new QoS mechanisms, which do not require buffers at the WDM layer in OBS networks. For that reason, this paper will propose an OBS network model using the per-hob-behaviors with its three methods of forwarding of the differentiated service to create the burst packets.

There are several critical issues affecting optical burst switched network such as contention resolution, channel and burst scheduling, burst assembly, signaling and quality-of-service (QoS) have been analyzed by researchers in order to find the utmost performance for a network that implement OBS.

In this paper, we will address one of the key problem mentioned above and that is the burst scheduling. The problem lies in designing the efficient algorithms for scheduling bursts or more precisely their bandwidth reservation. An ideal scheduling algorithm should be able to process a control packet fast enough before the burst arrives, and yet be able to find a suitable void interval for the burst as long as there exists one. Otherwise, a burst may be unnecessarily discarded either because a reservation cannot be completed before the burst arrives or simply because the scheduling algorithm is not smart enough to make the reservation. Given the fact that OBS uses one-way reservation protocols such as JET, and that a burst cannot be buffered at any intermediate node due to the lack of optical RAM, burst loss performance is a major concern in OBS networks. Hence, an efficient scheduling algorithm that can reduce burst loss by scheduling bursts both fast and in a bandwidth efficient way is of paramount concern in OBS network design.

The rest of the paper is organized as follows: In section II, we will look into the Queueing & Scheduling. In section III, we extend the discussion by looking into the related works on burst scheduling. In addition, section IV explained the proposed model for the burst hierarchical scheduling (WRR_PQ) and followed by its scheduler operation and results in section V. We finally conclude the paper in Section VI.

II. QUEUEING & SCHEDULING

Queueing controls the way packets are passed on to the output queue. Generally, they determine how packets are dropped when congestion occurs in a router. On the other hand,

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scheduling mechanisms ensure that different type of traffics obtain their share of resources such as link bandwidth and ensure that any spare capacity is distributed fairly. In other words it can be said that scheduler is responsible in reordering the output queue. Conventional schedulers such as First In First Out (FIFO), Priority Queueing (PQ), Fair Queueing (FQ) and Weighted Round Robin (WRR) have their own drawbacks [5]. Thus, hierarchical scheduling technique is introduced in this work to address these setbacks.

Edge scheduling can be viewed as the problem of sending the created bursts into the core such that the loss, delay and bandwidth constraints of each class are met. Edge scheduling is similar in some respects to traditional packet scheduling in IP routers and switches. In IP networks, packets are transported in a store-and-forward manner, with packet being sorted into prioritized buffers at each node, waiting to be scheduled for transmission.

Similar to IP networks, in an OBS network, the created burst will be sorted at the ingress node according to output port. However, in IP networks, each output port is normally associated with a static point-to-point transmission link. Hence, in the case of a contention at the source, where the intended output port is occupied by a transit burst of Priority *P*, the edge scheduling policy has to take into account the relative priorities of each new burst versus *P*. To guarantee QoS of packet classes, the mapping between burst priorities and burst types is an important issue in OBS networks.

The IP QoS literature is rich with packets scheduling policies [6]. It may be possible to adapt these policies for optical burst switched (OBS) network. It is assumes that once the bursts are created, they are placed in a prioritized burst queue corresponding to the appropriate output port.

III. RELATED WORKS ON BURST SCHEDULING

To the best of our knowledge, there is no existing work that investigates the hierarchical scheduling in the optical burst switched network. Instead, there are other mechanisms and algorithm that have introduced to burst scheduling.In [7], a minimum-starting-void (Min-SV) algorithm with FDL and batching FDL algorithm in use without FDL is proposed. For the Min-SV algorithm, it schedules a burst in o (log*m*) time, where *m* is the total number of void intervals, as long as there is a suitable void interval. Whereas in batch FDL algorithm, it considers a batch of FDLs to find a suitable FDL to delay a burst which would otherwise be discarded due to contention, instead of considering the FDLs one by one.

The authors in [8] propose the use of OBS group scheduling in which a burst is represented by an interval of time. The process of scheduling a number of bursts, thus, turns to be a process of fitting a set of the corresponding time intervals on a channel time line that represents a channel-time resource. Differentiated Scheduling (DS) [9], is the method whereby dynamically choosing the early differentiation time, each OBS node can adjust the data burst loss rates for different classes of bursts and satisfy differentiated QoS requirement with the available resources.

Partially preemptive scheduling technique [10] is proposed to handle data bursts in parts and may use preemption due to the priorities of data burst in a multi-service OBS network environment. On the other hand, a burst overlap reduction algorithm (BORA) is being developed in [11] to schedules locally assembled bursts in such a way as to reduce burst contention at downstream nodes in OBS network.

IV. Proposed Work on Hierarchical Scheduling: WRR_PQ technique

Once the burst is created, it must be sent into the OBS core. This work suggests that the created bursts are sent using hierarchical scheduling in DiffServ ingress edge router where the design in based on the DiffServ network model shown below in Figure 2 for the OBS network.

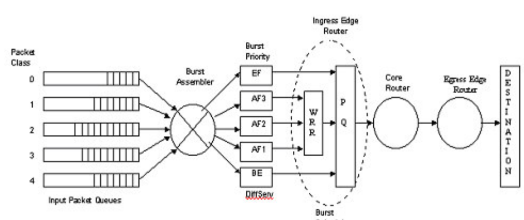

Figure 2: Propose OBS Network Model

A hierarchy of a rate based scheduler and priority scheduler are proposed here. Rate based scheduler are basically schedulers with weight assigned to each service classes such as WRR while PQ is an example of a priority scheduler. WRR only schedules AF traffic that are not sensitive to time compared to EF traffic while BE is not included in WRR level because it is considered the lowest priority traffic. WRR is used in this work to schedule different classes of AF traffic before it is being scheduled using PQ with other EF and BE traffic. The propose network model for the hierarchical burst scheduling is shown in Figure 3.

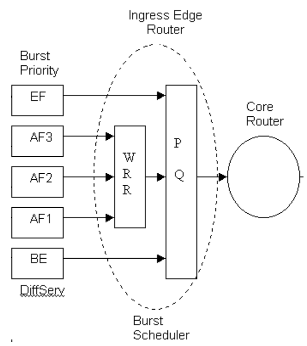

Figure 3: Propose Burst Hierarchical Scheduling Model

PQ is very useful for EF traffic where priorities can be set so that the real time applications get priority over applications that are not time crucial. However, the main disadvantage of this system is that if a higher priority queue is always full, the lower priority queues will never be served. Thus, a particular kind of network traffic may dominate a PQ interface and lower priority traffic may experience excessive delay as it waits for higher priority traffic to be served. If lower priority queues are dropped due to the buffer overflow, the combination of packet dropping latency will be increased and packet retransmission by host system can lead to resource starvation for lower priority traffic.

In contrast, WRR controls the percentage of bandwidth allocated to each service class. Thus, bandwidth starvation could be avoided. WRR is also efficient in providing mechanism to support delivery of DiffServ classes to a reasonable number of highly aggregated traffic flows. The main limitation of WRR is that it gives the correct percentage of bandwidth to each service class only if all bursts in all queues are in equal size or when the mean burst size in known in advance. Due to the RR nature of the algorithm, WRR tends to increase the queueing delay and jitter for EF traffic. Therefore, it is envisaged that WRR_PQ technique will improve the limitations of both WRR and PQ schedulers in egress edge router of DiffServ domain.

V. WRR_PQ SCHEDULER OPERATION & RESULTS

When a new burst arrives, classify the burst into class EF, AF3, AF2, AF1 and BE;
For burst classified as AF3, AF2 and AF1 apply Weighted Round Robin (WRR) with the following weights;

AF3 = 5
AF2 = 3
AF1 = 1

At the same time for burst classified with EF and BE are scheduled together with AF burst from the above WRR using Priority Queuing (PQ) as follows:

EF = highest priority
AF = medium priority
BE = lowest priority

The simulation model of Figure 3 is validated in terms of its behaviour compared to queuing theory. In the validation process, the proposed network model will serve heterogeneous incoming traffic flows, which follow Poisson distribution. As a result of that, the suitable model for this network in queuing theory is M/G/1 where M (memoryless) with Poisson arrival process, intensity λ, G (general) with general holding time distribution, mean $S = 1/\mu$ and 1 refers to a single server, load $\rho = \lambda S$.

The most well known result for M/G/1 queue is the Pollaczek-Khinchin (P-K) mean formula, which gives the following mean waiting time in the queue, *W*.

$$E[W] = E[N_q] \times E[S] + E[R]$$

$E[W]$ = Mean time needed to serve the Customers ahead in the queue
$E[N_q]$ = number of waiting customers
$E[S]$ = mean service time
$E[R]$ = unfinished work in the server

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The average waiting time in such a scenario is given by (P-K) formula:

$$W = \frac{\lambda \cdot X^2}{2(1-\rho)}$$

Using Little's formula, average number of traffic in the system, N is derived as follows:

$$N = \lambda T$$

The average number of traffic in a queue, N_q can be determined as follows:

$$N_q = \lambda W$$

Thus, N_q for M/G/1 system is:

$$N_q = \frac{\rho^2}{2(1-\rho)}$$

The following Figure 4 shows a graph for the preliminary result tested on the propose OBS network model taking into account the given initial parameters.

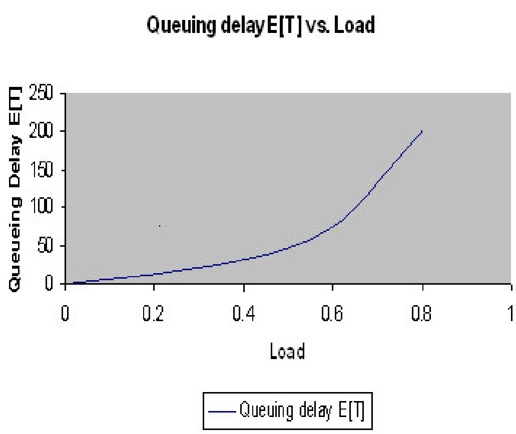

Figure 4: Queueing Delay

Parameters:

Burst Size	10 packets
Packet Size	1500 bytes
Link Rate	150 Mbit/s
Buffer	Unlimited
Traffic	Poisson
Signaling	JET
Routing	MPLS

$$\text{Total Delay} = \text{Queueing Delay } E[T] + T_{OFFSET} + T_P + T_B$$

It is expected that by implementing these three mechanisms, the QoS in terms of:

•high resource utilization,
•low delay and jitter for real-time traffic and
•low burst loss ratio can be obtain.

VI. CONCLUSIONS

Optical Burst Switching (OBS) has been proposed as a future high-speed switching technology for all-optical networks that may be able to efficiently utilize extremely high capacity links without the need for data buffering or optical-electronics conversions at intermediate nodes. Packets arriving at an OBS ingress node that are destined for the same egress OBS node and belong to the same Quality-of-service (QoS) class are aggregated and sent in bursts. At intermediate nodes, the data within the optical signal is transparently switched to the next node according to forwarding information contained within a control packet preceding the burst. At the egress node, the burst is subsequently de-aggregated and forwarded electronically. Unlike classical circuit switching, contention between bursts may cause loss within the network.

The main problem of OBS is that this loss is quite high, even for moderate input loads. By measuring, managing and reducing loss, the novel techniques introduced in the earlier chapters can overcome serious hurdles in optical burst switching and ensures the feasibility of OBS and eventual deployment.

With the implementation of the proposed burst hierarchical scheduling (WRR_PQ), it is expected that the network performances of the OBS network model will be able to give better

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QoS in terms of low burst loss ratio, low blocking probability and high resource utilization.

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